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DEVELOPMENT OF A MICROCOMPUTER BASED SOFTWARE SYSTEM FOR USE IN CREWMEMBER EJECTION ANALYSIS

Nagarajan Rangarajan
General Engineering and Systems Analysis Company, Inc.
8607 Second Avenue, Suite 306
Silver Spring MD 20910

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HARRY G. ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY
HUMAN SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WIRGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6573

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FOR THE COMMANDER

James W. Brinkley

JAMES W. BRINKLEY
Director
Biodynamics and Bioengineering Division
Harry G. Armstrong Aerospace Medical Research Laboratory

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A prototype of DYNAMAN, which is an implementation of the Articulated Total Body (ATB) Model on PCs, has been developed. DYNAMAN is an interactive software which can be used to analyze the dynamics of vehicle occupants and crewmember ejection problems. It is menu driven and is comprised of the preprocessor, the simulation module and the postprocessor. DYNAMAN will run on Intel 80286 based machines with appropriate math coprocessors.

The preprocessor allows the analyst to set up, interactively, the input data set for the simulation module. The simulation module accepts input data sets created by the preprocessor and standard ATB-IV.0 input data sets and produces picture, plot and print output files. The simulation module also calculates common injury measures such as the Chest Severity Index (CSI), Head Severity Index (HSI), and Head Injury Criteria (HIC). The postprocessor can be used to examine the motion of the vehicle occupant, and to obtain plots of various dynamic variables or to view them as tables.

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Development of a Microcomputer Based Software System

for Use in

Crewmember Ejection Analysis.

This report is being submitted to fulfil the requirements of contract number F33615-88-C-0544. The contract was issued to cover work to be done in Phase I of the FY-1988 SBIR solicitation, topic number AF 88-072.

In this report, we will discuss the reasons for undertaking the development of the software, describe the work carried out during Phase I and the results of this work. We will also summarize potential applications of this work.

1.0 Introduction

The Crash Victim Simulation (CVS) model was developed by Calspan corporation under the joint sponsorship of the Motor Vehicle Manufacturers Association (MVMA) and the National Highway Transportation Safety Administration (NHTSA). CVS was to be used to simulate the three dimensional dynamic responses of a motor vehicle crash victim. The result of these development efforts was the CVS - III computer program.

The Armstrong Aerospace Medical Research Laboratory (AAMRL) funded further enhancements to the CVS resulting in the development of the Articulated Total Body Model (ATB) which could be used to study the dynamics of crew members ejecting from high-speed aircraft.

Currently, the ATB model is resident on mini-computers such as the Perkin-Elmer at AAMRL and the VAX 11/780 at the NHTSA. ATB is generally executed in batch mode and the turn around time required to complete a given simulation will depend on the system load. Also, a large number of medium and small companies working under government contracts which do not have access to mini-computers have to exercise the model on government owned computers or install the software on machines provided by outside time-share vendors.

An alternative that will be attractive to a large number of users is to make the model available on microcomputer based workstations. Recent developments in micro-computer hardware and software technology have made it possible to develop such a workstation. The price of such a workstation would be within the reach of many small companies.

2.0 Purpose and Technical Objectives of Phase I Efforts

The purpose of Phase I efforts was to develop an interactive, micro-computer based version of the ATB. As noted above, such a system would make it easy for a large number of small and medium sized contractors to model the performance of restraint systems and ejection seats in a cost-effective and timely manner.

With this purpose in mind, we divided Phase I effort into the following ten tasks:

1. Download ATB version 4.0 onto an Intel 80386 based microcomputer, compile and link the FORTRAN source code to create an executable file.

2. Develop plotting routines to plot the output from the model on CGA, EGA and VGA monitors.

3. Develop graphics routines to display the motion of the occupant at various time steps during the simulation on CGA, EGA and VGA monitors.

4. Download the current version of GEBOD to the micro-computer and produce an executable file.

5. Develop a master menu program which will allow the user to choose various options available as a part of the integrated software.

6. Examine the possibility of developing on-line help utilities which will guide the user in the operation of the software.

7. Search literature to obtain mechanical properties of human hard tissues and tabulate them.

8. Search literature to identify appropriate finite element formulations that will use the output from ATB model and data from the data base of mechanical properties of hard tissue to calculate stresses and strains on structures made up of hard tissue.

9. Generally, hard tissue injury has been correlated with stresses and strains developed in the structure due to external loading. By surveying literature, we will identify appropriate methods to correlate injury measures to the stresses and strains that will be obtained as outputs of the finite element models.

10. Produce a final report at the end of Phase I.

In sections 3, 4 and 5, respectively, we will describe the work carried out during Phase I, list the goals achieved and the potential applications of the results of Phase I efforts.

3.0 Description of Work Carried out in Phase I

We gave the name "DYNAMAN" to the PC based integrated crew member ejection analysis software. We also decided to split the software into a Preprocessor, a Simulation module and a Postprocessor. The development efforts were split into the following five phases:

1. Development of a 16-bit Simulation module.
2. Development of Postprocessor.
3. Development of Preprocessor.
4. Development of On-line help facility.
4. Development of a 32-bit Simulation module.

In the next three sections, we will describe the development of the these three modules.

3.1 Development of the 16-bit Simulation module

During Phase I, we downloaded the ATB version 4.0 and the AAMRL VIEW source (FORTRAN) codes to a 80386 based microcomputer. Initially, we used the 16-bit Microsoft FORTRAN 4.01 compiler to compile and link the program. The size of the resulting executable module was too big to fit within the limits of the memory that could be addressed by DOS (640K RAM). After some experimentation, we developed an overlay structure which allowed us to reduce the size of the executable module and at the same time run the program efficiently.

The next step was to verify the DYNAMAN code running on the 80386 based machine. This was done by selecting an input data set and running a simulation on the NHTSA VAX 11/780 using this input data set. The values of segment angular and linear accelerations, velocities and displacements estimated by the ATB 4.0 on the VAX were printed out and compared with the respective variables estimated by DYNAMAN. We found significant discrepancies between the values of variables estimated by ATB and DYNAMAN. The source of this discrepancy was traced to the word length in double precision between VAX and the PC. To reduce these errors, we traced some small numbers of the order of 10^{-12} to the belt strain calculations. We then set all numbers less than 10^{-12} equal to zero as 10^{-12} represents the limit of precision for double precision numbers on the VAX. Once this was done, we found agreement between results predicted by DYNAMAN and the VAX version of ATB 4.0 to seven significant figures. We repeated this test with various input data sets and confirmed

that the results produced by ATB 4.0 agreed with those produced by DYNAMAN.

Once we developed a reliable simulation module, we turned our attention to the development of post- and pre processors as described in the next two sections.

3.2 Development of the Postprocessor

In this section, we will describe the development of the Postprocessor. The output of DYNAMAN consists of files containing data which will enable the analyst to obtain a time-history plot of the various dynamic variables and data that would enable the analyst to view pictures depicting the motion of the vehicle occupant during the simulation.

We decided to use the pull down menu structure in the postprocessor. We also decided to use existing code from the AAMRL VIEW program to the extent possible in the development of the postprocessor. Other considerations in the design of the postprocessor were that:

1. It should be interactive.
2. It should support CGA, EGA and VGA display systems.
3. It should display any harness belts, airbags and extra segments used in the simulation.
4. It should be possible for the user to route plots and pictures generated by the postprocessor to Epson and HP LaserJet compatible printers.
5. It should be possible for the user to obtain tabular time-histories of dynamic variables and display them on the screen, route them to a printer or to store them on disk files.

We downloaded the VIEW program onto the 80386 machine and recompiled it on the PC. We separated the plotting routines from the ATB 4.0 program and integrated it with the postprocessor. We developed interface routines that translated CALCOMP calls in the plotting and viewing routines (in the AAMRL VIEW program) into calls that were compatible with a graphics library developed by us. This library supports CGA, EGA and VGA display systems.

We debugged and tested the postprocessor after development was completed.

3.3 Development of the Preprocessor

The development of the preprocessor was perhaps the most challenging task in the development of DYNAMAN. The criteria used in the design and development of the preprocessor are listed below:

1. It should be interactive and have a pull down menu structure.
2. Data should be entered on well designed screens and data entry should be format free.
3. Mnemonics should be used wherever possible to indicate to the user the type of data to be typed in.
4. The simulation input file produced by the preprocessor should be in the ATB 4.0 format so that any data set produced by DYNAMAN can be used by the ATB 4.0 program running on main frames or mini computers.
5. The preprocessor should be able to read any existing ATB 4.0 input file and display it on the screen so that the user can edit it with minimum effort.
6. Where possible, the preprocessor should read blocks of data pertaining to one element in the simulation. For example, it should be able to read in a data file that contains occupant data or plane data in ATB 4.0 format.
7. The analyst should be able to insert or delete records from the input file with minimum effort.
8. The analyst should be able to change the position of the occupant interactively to obtain equilibrium of contact forces.
9. The analyst should be able to interactively define the number of harness belts, the number of belts in each harness and the position of reference points for each belt using function keys and arrow keys found on the keyboard.
10. The analyst should be able to define various contact and joint restoring functions interactively and see a plot of the functions on the screen.

In order to meet the above requirements, we rationalized the card structure used to input data into the ATB 4.0 input data file. We used calls to a graphic library developed by us to develop data input screens, and to project the position of the occupant, the vehicle interior and harness belts on the screen.

We tested, debugged and validated the operation of the preprocessor after development was completed.

3.4 Development of the On-line Help facility.

After completing the development of the pre- and post processors and the 16-bit simulation module, we decided to concentrate on the development of the On-line Help facility. We developed help messages to guide the user at various levels in the operation of the pre- and post processors. These messages were compiled into a message file and we inserted calls at various points in the pre- and post processor source codes to call the appropriate messages from the message file and display them on the screen. A prototype of the On-line Help facility was developed as a part of Phase I efforts and we hope to complete the development during Phase II.

3.5 Development of 32-bit Simulation module.

Once the development of the pre- and post processors, the 16-bit Simulation module, and the On-line help facility was completed, we started the development of the 32-bit Simulation module. We used the Microway 32-bit compiler together with a DOS extender developed by Phar Lap Software, Inc. to compile the FORTRAN programs that made up the simulation module. Since we used a DOS extender, the ATB program could be compiled in its entirety without an overlay structure. The size of the resulting executable module was about 500 Kb. The size of the program when loaded and executing on the PC was found to be about 1.2 Mb.

While testing the 32-bit Simulation module, we found some bugs in the compiler and these bugs have been reported to the developer who has promised to fix them and inform us when they have been fixed. So, the 32-bit simulation code is not yet ready. We hope to complete this work in Phase II of this contract.

4.0 Results of Phase I Efforts

During Phase I, we have developed a working prototype of DYNAMAN, a microcomputer based software system for use in crewmember ejection analysis. The software is interactive and easy to use. DYNAMAN consists of the following three modules:

1. A preprocessor.
2. A simulation module.
3. A postprocessor.

An On-line Help facility guides the users in the operation of the various modules and in entering data. We also developed a Users Manual for the software.

Apart from ease of use, the other design criterion that we were guided by in the development of DYNAMAN was that execution times for a simulation using DYNAMAN on a PC should be comparable to that on VAX 11/780 mini-computer. In order to check if we had met this goal, we ran a 150 ms simulation on the VAX and a 20MHz 80386 based PC. The input data set described a Hybrid III dummy with lap and shoulder belts, sitting on a sled seat. We defined five contact planes and exposed the car to a 30 mph change in velocity with peak deceleration of about 30 Gs. We ran the simulation on the NHTSA VAX 11/780, when there were only two users and the simulation was completed in 6 to 8 minutes depending on the amount of system back up in progress. When the 32-bit simulation module was run on the PC using the same input data set, simulation was completed in 11 minutes. When the 16-bit simulation module was used, it took about 35 minutes to complete the simulation. When we ran the simulation using the 16-bit code on a 12 MHz 80286 based machine, simulation was completed in about 1 hr and 40 mins.

Finally, our staff demonstrated the operation of the software to the Contracting Officer's Technical Representative (COTR) and other personnel at AAMRL and solicited their comments. The staff at AAMRL were pleased with the design and operation of the software.

5.0 Potential Applications of Phase I Efforts.

The results of Phase I efforts have demonstrated the feasibility of developing PC based crew member ejection analysis software. The prototype software developed in Phase I can be used by contractors and DoD components to analyze the dynamics of crew members during complex ejection events. However, some enhancements need to be made to the software in order to make it more useful to the Air Force. We have addressed these enhancements in our Phase II proposal.